Claims

What is claimed is:

1. A solid-propellant gas generator for well stimulation, comprising:

a tubular assembly of propellant charge having an outside surface and a central channel, part of the assembly being clad on its outer surface to prevent burning from that surface, and part of the assembly being bare on its outer surface; and

an igniter arranged to initiate burning of the propellant charge along the whole length of the central channel and the bare part of the outer surface.

2. A gas generator according to claim 1, wherein the propellant charge comprises a plurality of cylindrical charges stacked end to end, and wherein at least one of the charges is clad and at least one of the charges is bare.

3. A gas generator according to claim 2, wherein the at least one clad charge is covered by a layer of substantially incombustible material adhering to the surface of the charge.

4. A gas generator according to claim 3, wherein the cladding layer on the least one clad charge overlaps and protects the end of an adjacent bare charge.

5. A gas generator according to claim 3, wherein there are a plurality of adjacent bare charges, and the join between them is encased in a protective ring.

6. A gas generator according to claim 2, which comprises a plurality of clad charges and a plurality of bare charges, and wherein all the clad charges are adjacent and all the bare charges are adjacent.

7. A gas generator according to claim 6, wherein the igniter is positioned within the endmost bare charge.

8. A gas generator according to claim 2, which comprises a primary charge having the igniter positioned within its central channel.

9. A gas generator according to claim 8, wherein the primary charge is a bare charge.

10. A gas generator according to claim 8, wherein the diameter of the central channel of the primary charge is greater than that of other charges.

11. A gas generator according to claim 1, comprising an attachment for a cable to lower the gas generator into a well.

12. A gas generator according to claim 11, wherein the igniter is at a lower end of the gas generator, and is provided with an attachment for a cable passing along the central channel.

13. A gas generator according to claim 12, comprising a lower end cap attached to the igniter.

14. A gas generator according to claim 13, comprising an upper end cap with an attachment for the cable, and arranged to hold the cable in tension in the channel and the charge in compression.

15. A gas generator according to claim 11, comprising a cable to lower the gas generator into a well.

bit ~~16.~~ A gas generator according to claim 1, wherein the bare part of the charge comprises a charge having an expanded initial burning surface.

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FIG 3

17. A gas generator according to claim 1, wherein the charge having an expanded initial burning surface comprises a slotted charge, and wherein the igniter is arranged to initiate burning of the propellant charge along the surfaces of the slots.

18. A gas generator according to claim 1, which is so constructed that the rate of gas generation immediately before the bare part burns out is substantially equal to the rate of gas generation immediately before the clad part burns out.

METHOD

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19. A gas generator according to claim 1, which is so constructed that the area of the burning surface immediately before the bare part ~~burns out is~~ substantially equal to the area of the burning surface immediately before the clad part burns out.

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20. A gas generator according to claim 1, wherein the ratio λ of the total length H of the bare part to the total length H_{inh} of the clad part is given by the equation:

$$\lambda = \frac{\overset{BARE}{H}}{\underset{CLAD}{H_{inh}}} = \frac{D_0 - d_0}{2(D_0 + d_0)}$$

where D_0 and d_0 are outer and inner tubular charge diameters, respectively.

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21. A gas generator according to claim 1, comprising charges having an expanded initial burning surface as said bare charges, and wherein the ratio λ of the total mass m of the bare part to the total mass m_{inh} of the clad part is given by:

$$\lambda = \frac{\overset{BARE}{m}}{\underset{CLAD}{m_{inh}}} = \frac{4(D_0 - d_0 - 2e).e}{D_0^2 - d_0^2}$$

where e is the thickness of the burning web of the charges having an expanded initial burning surface.

22. A gas generator according to claim 1, wherein the igniter is a detonating igniter that comprises a tube fitting within the central channel, a detonating fuse in a perforated part of the tube, an explosive cartridge in a protective case positioned to ignite the detonating fuse, and a flash charge of mixture propellant surrounding the detonating fuse and arranged to be ignited by the detonating fuse and to ignite the propellant charge.

23. Solid-propellant gas generator with adjustable pressure pulse for well stimulation, comprising:

tubular propellant charges coated on their outer surface;

a primary charge installed below said tubular coated propellant charges, and provided with a device for its firing;

tubular bare charges installed between the primary charge and the charges coated along the outer surface; and

a load-carrying geophysical cable with construction attachment elements;

wherein the ratio λ of the total length H of the bare charges to the total length H_{inh} of the coated ones is given by the equation:

$$\lambda = \frac{H^{\text{BARE}}}{H_{inh}\ (\text{COATED})} = \frac{D_0 - d_0}{2(D_0 + d_0)}$$

where D_0 and d_0 are outer and inner tubular charge diameters, respectively.

24. Solid-propellant gas generator with adjustable pressure pulse for well stimulation, comprising:

tubular propellant charges coated on their outer surface;

a primary charge installed below said tubular coated propellant charges, and provided with a device for its firing;

tubular bare charges having an expanded initial burning surface installed between the primary charge and the charges coated along the outer surface; and

a load-carrying wifelike with construction attachment elements;

wherein the ratio **λ** of the total length **m** of the bare charges to the total length $\mathbf{m}_{inh}$ of the coated ones is given by the equation:

BASE

$$\frac{m}{m_{INH}} = \lambda = \frac{4(D_0 - d_0 - 2e).e}{D_0^{\,2} - d_0^{\,2}}$$

[illegible]

where $\mathbf{D}_0$ and $\mathbf{d}_0$ are outer and inner tubular charge diameters, respectively; and

e is the thickness of the burning web of the charges having an expanded initial burning surface.

25. The gas generator according to claim 24, comprising a detonating igniter that consists of a perforated tube, an explosive cartridge in a protective case, a flash charge of mixture propellant, and a detonating fuse installed in its channel.

26. A method of assembling a solid-propellant gas generator, which comprises assembling, end to end:

an upper and a lower end cap;

at least one tubular charge defining a central channel and coated on its outer cylindrical surface to resist burning; and

at least one tubular charge, bare on its outer surface, of the same inside and outside diameters as said at least one coated charge;

placing an igniter within the central channel of said at least one bare tubular charge; and

attaching to the upper and lower end caps a cable for lowering the gas generator into a well.

27. The method according to claim 26, wherein said at least one bare tubular charge comprises a primary charge, which has the igniter installed within its central channel; wherein said method comprising attaching said cable at an upper end of said igniter; and wherein said lower end cap is attached to said cable by being attached to said igniter.

28. A method according to claim 26, which comprises assembling the at least one coated charge at the top end of the gas generator, and any further bare charges between the primary charge and the coated charges.

29. A method according to claim 26, which comprises securing the upper and lower endcaps to the cable to hold the charges in compression.

30. A method according to claim 26, which comprises selecting the bare and coated charges such that the total length of coated charge is approximately twice the total length of the bare charges.

31. A method according to claim 30, which comprises selecting the bare and coated charges such that the ratio λ of the total length H of the bare charges to the total length H_{inh} of the coated ones is given by the equation:

$$\lambda = \frac{H}{H_{inh}} = \frac{D_0 - d_0}{2(D_0 + d_0)}$$

where D_0 and d_0 are outer and inner tubular charge diameters, respectively.

32. A method according to claim 26, wherein the bare charges comprise charges having an expanded initial burning surface.

33. A method according to claim 32, which comprises selecting the bare and coated charges such that the ratio λ of the total mass m of the bare charges to the total mass m_{inh} of the coated ones is given by:

$$\lambda = \frac{4(D_0 - d_0 - 2e).e}{D_0^2 - d_0^2}$$

where D_0 and d_0 are outer and inner tubular charge diameters, respectively, and

e is the thickness of the burning web of the bare charges.

34. A method of stimulating a well, which comprises lowering a gas generator according to claim 1 into the well, positioning it at the level of a productive formation to be stimulated, activating the igniter, and thereby igniting the central cylindrical surfaces of both the bare and the coated charges and the outer cylindrical surfaces of only the bare charges of the gas generator.

35. A method of stimulating a well, which comprises assembling a gas generator by a method according to claim 26, lowering the gas generator into the well, positioning it at the level of a productive formation to be stimulated, activating the igniter, and thereby igniting the central cylindrical surfaces of both the bare and the coated charges and the outer cylindrical surfaces of only the bare charges.

36. A method according to claim 34, which comprises generating by means of the propellant charge a pressure sufficient to expand fractures in the productive formation for a period greater than 0.5 seconds.

37. A method according to claim 34, which comprises generating by means of the propellant charge a pressure that rises to a peak as both the bare and the coated charges burn, and rises to a second peak approximately equal to the first peak as the coated charges continue to burn after the bare charges have burnt out.